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(54) IMPROVEMENTS IN FLEXIBLE TUBE

(71) I, BARRIE FINBARR WHITWORTH, a British subject of Lower Green House, Hove Edge, Brighouse, Yorkshire, HD6 2PT, do hereby declare the invention, for which I pray that a patent may be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns a method and apparatus for producing helically convoluted flexible tube. In particular though not exclusively the invention is concerned with the method and apparatus for producing helically convoluted flexible tube adapted to be used as pressure hose or electrical conduit.

It is known to produce flexible tube in convoluted form from material such as polytetrafluroethylene (PTFE) and while such tube adequately serves the purpose for which it was manufactured it is found that there are several disadvantages. For example, the technique of manufacture, by blow moulding; heat and pressure moulding or the like are relatively costly to carry out and thus the end product is costly. Thus it is an object of the present invention to provide a method and apparatus for producing helically convoluted flexible tube in a manner such that cost savings can be made.

Thus according to one aspect of the present invention there is provided a method of producing helically convoluted flexible plastics tube comprising the steps of threading a pre-formed plain flexible tube over an axially movable, non-rotatable plain surfaced cylindnical mandrel, moving said mandrel and tube through a rotary convolution forming head and applying, by means of the head, a convolution retaining element to the tube the said head being so shaped as to wind the retaining element in helical manner around said tube at pre-set pitch to convolute said tube, and thereafter either removing the convolution retaining element or allowing it to remain when the tube has set into convoluted form either by cold compression or heat treatment and removing the convoluted tube so formed from the mandrel.

Conveniently to produce convolutions of a closer pitch than those formed by the initial convoluting process, the convoluted tube while on the mandrel is compressed axially and is so retained by retaining members during heat treatment and subsequent cooling in air, whereafter the retaining members are removed and a heat stable close pitch convoluted tube is removed from the mandrel, the convolution retaining element the tube then being retained or removed.

Alternatively the wound convoluted tube is located on a mandrel, a close pitch or touch pitch spring being also mounted on the mandrel in tandem with the tube, said spring being extended to a pitch approximately equal to the pitch of tube convolutions and so retained, partially removing the convolution retaining element of the tube and rotationally threading it into or onto the extended spring, unwinding the remainder of the convolution retaining element to rotate the tube and 'screw' it into or onto the spring, subsequently removing the re-wound tube and subjecting it to heat treatment to soften the material thereof and allow the spring to return to its close pitch form to produce close pitch convolutions in the tubes, cooling the tube in air and either retaining or removing the spring.

The invention also includes apparatus for producing helically convoluted flexible tube, said apparatus including a mandrel and a convolution forming tool, said mandrel being non-rotatable but movable axially through said tool, said tool being rotatable around said mandrel and being provided with a helical guide formation adapted to receive a convolution retaining element whereby in use by the combined rotation of the tool and helical feed of the convolution retaining element serves to cause axial movement of the mandrel through the tool as the convolution retaining element is helically formed around the tube contained on said mandrel.

Preferably the tool is mounted on a rotatable backplate through which the mandrel amy pass, the backplate carrying means for rotatably receiving a convolution retaining element supply spool and means for applying a restraining force to the spool to control its freedom to rotate thereby to provide tensioning means for the convolution retaining element.

The invention will now be described further, by way of example only, with reference to several practical forms thereof and the accompanying diagrammatic drawings in which:

Figure 1 shows in perspective part of a machine for producing convoluted tube in accordance with the invention.

Figure 2 illustrates in side elevation a machine for producing convoluted tube.

Figure 3 Illustrates part of the machine of Figure 2 showing how a modified form of convoluted tube is produced.

Figure 4 is a view similar to Figure 3 showing how a still further modified form of convoluted tube may be produced.

Figure 5 Illustrates on a larger scale and in cross-section part of the apparatus of Figure 2.

Figure 6 is a view in the direction of the arrow A of the apparatus shown in Figure 5.

Figures 7, 8 and 9 are respectively a cross-section, a side elevation and a perspective view of a part of the apparatus, used as a guide for a convolution retaining element such as a wire to be wound around a tube to be convoluted.

Figure 10 Illustrates to a larger scale part of a convoluted tube made on the machine of any one of Figures 2 to 4 is fitted with an end fitting, the part sectional upper portion of the figure showing the end fitting before a swaging operation and the lower portion showing the fitting after swaging, and Figures 11 and 12 show alternative forms of convolution retaining element in the production of reinforced, convoluted tube.

An apparatus for producing helically convoluted flexible tube comprises, as shown particularly in Figure 1, a first mandrel 10 of circular cross-section having at one end a diametrically located slot 11. The other end of this mandrel is held in a clamp 12 so that it is non-rotatable. The clamp 12 is located in a slide 13 mounted horizontally on a machine bed 14 (see Figure 2) and the first mandrel 10 is located in parallelism with the slide 13. The first mandrel 10 can therefore move axially whilst being restrained against rotation. At one end of the slide 13 the machine bed 14 is provided with a mounting block 15 (see Figures 2 and 5) upon which are bearings 16 containing a second, rotatable, hollow tubular mandrel 17. Below the second mandrel 17 and conveniently within the mounting block 15, is a prime mover (not shown) which, through a suitable gear drive 18 (see Figure 2) is adapted to rotate the second mandrel 17. At that end of the second mandrel 17 located nearer to the slide 13 is mounted a face plate 19 (see Figures 2, 5 and 6) having a central aperture 19a through which the axially movable first mandrel 10 can pass to enter and pass through the second, rotatable, mandrel 17. Surrounding the central aperature 19a of the face plate 19 is a helix forming tool 20 comprising a disc like element 21 having a central aperture 22 corresponding in size to the aperture 19a in the face plate 19 to which, from the periphery of the tool 20 is formed a convolution retaining element guide hole 23. In the particular embodiment being described the convolution retaining element is in the form of a wire 25. The inner periphery of the tool 20 is grooved, as shown at 24 in Figures 6, 7, 8 and 9 and serves to guide the wire 25 and in addition the tool 20 is formed so that part 26 of the disc 21 adjacent the central aperture 22 is deformed from the flat condition into a helical shape. Mounted eccentrically on the face plate 19 is a spindle 27 (see Figure 5) onto which can be rotatably mounted a spool 28 around which the convolution retaining wire 25 is wrapped. The free end of the spindle 27 is threaded to received a tension nut 29. The spindle 27 is surrounded at the face plate 19 with a friction pad 30 of disc form. Between the tension nut 29 and the spool 28 is provided a spring 31 thus adjustment of the nut 29 will hold, to a greater or lesser extent, the spool 28 against the friction pad 30 and thus a predetermined unwinding tension can be provided for the wire 25 wrapped on the spool 28.

To produce a helically convoluted flexible tube such as a pressure hose a length of plain pre-formed tube 32 such as polytetrafluoroethylene (PTFE) is threaded onto the first, non-rotatable, mandrel 10. The tube 32 is of somewhat larger internal diameter than the external diameter of the first, non-rotatable, mandrel 10. For example, if the mandrel 10 has a diameter of 0.532 inches the internal diameter of the tube 32 may be 0.625 inches and the wall thickness 0.020 inches. It follows therefore that when the wire is helically wound around the tube 32 under tension it serves to retain a helical convolution formed along the length of the tube, the depth of the convolution being a function of the clearance between the inner wall of the tube and the surface of the mandriel 10 combined with the pitch of the convolutions. Before locating the tube 32 on the first, non-rotatable, mandrel 10 one end 33 of the tube 32 is cut at approximately 45° to the axial centre line of the tube 32. This cut end 33 is located at that end of the first, non-rotatable, mandrel 10 remote from the clamp 12.

The first mandrel 10 is positioned with its clamped end 10a at the end of the slide 13 remote from the tool 20 such that a section of the first, non-rotatable, mandrel 10 adjacent its free end is not covered by the tube 32. Wire 25 from the spool 28 is drawn through the hole 23 in the tool 20 and located around the groove 24 of the inner periphery of the tool 20 and the non-rotatable mandrel 10 is advanced

towards the tool 20 until the free end of the wire 25 can be located in the diametrically disposed slot 11. The machine is now set up for the production of the helically convoluted tube and with the prime mover energised the face plate 19 is caused to rotate by virtue of rotation of the hollow mandrel 17 and thus wire 25 from the spool 27 is wrapped onto the uncovered free end of the non-rotatable mandrel 10 under pre-set tension and thus due to the helical form of winding of the wire 25 serves to draw the non-rotatable mandrel 10 towards and through the hollow mandrel 17. Thus as the non-rotatable mandrel 10 is drawn through the hollow mandrel 17 the wire 25 is wound in helical configuration at controlled tension and pitch onto the tube 32 thus to cause the tube 32 to become convoluted as shown at 34. When the whole of the tube 32 has been wrapped the latter, together with the wire wrapping 25 is removed from the non-rotatable mandrel 10. The convolutions in the tube 32 at this stage in the manufacturing process are not particularly deep since in the example given there are only .093 inches difference between the outside diameter of the non-rotatable mandrel 10 and the inside diameter of the tube 32. The so formed convoluted tube 34 is now axially compressed to reduce the pitch of the helical convolution and thus from deeper convolutions at close pitch due to cold compression set of the PTFE tube material. When the convoluted tube 34 is cold set the wire 25 which lies at the root of the convolutions may either be removed or left in place as a reinforcement.

In an alternative form of manufacture using substantially the same apparatus, it is possible to produce a tube in which the pitch of the convolutions is extremely small. In order to produce such a tube the initial convolutions are produced as described above and then the tube is, as shown in Figure 3 and whilst on the non-rotatable mandrel 10 compressed to "touch pitch", by which we mean that the wound tube in compressed until the convolutions are brought into contact with each other. In this condition the compressed convoluted tube 34 is clamped by clamps 35 mounted on the non-rotatable mandrel 10. The so compressed tube 34 is then heat treated at approximately 320°C (assuming the material of the tube is PTFE) for a pre-set period of time. The heated tube 34 is then allowed to cool and when cooled the clamps 35 are removed and thus the heat treated and set convoluted tube 34 may then be removed from the non-rotatable mandrel 10. If desired the wire 25 (which preferably is stainless steel) may be removed from the root of the convolutions or of course it may be retained as a reinforcement.

In a still further modification of the manufacturing process a tube produced in the manner described above to have the initial form of convolution is retained (as shown in Figure 4) on non-rotatable mandrel 10 in such a position that over a non-covered portion of the non-rotatable mandrel 10 a close wound spring 36 of, for example, carbon steel of internal diameter 0.580 inches of wire of 0.040 inches diameter (wound for example to touch pitch) is threaded over the uncovered portion of the mandrel 10 and its end 36a remote from the slightly convoluted tube 34 is clamped on the mandrel 10. The spring 36 is then extended as shown until the pitch of its coils is approximately the same as the pitch of the convolutions of the convoluted tube 34. Thus the extended spring 36 and the tube 34 lie in series on the same mandrel 10. The leading end, that is the end nearest the extended spring 36, of the convoluted tube 34 is wound free of the wire 25 used to produce the initial convolutions and the unwrapped end of the convoluted tube 34 end is, by rotation of the tube 34, screwed into the end of the extended spring 36. By then continuing to unwind the wire 25 from the tube 34 the latter can be screwed completely into the extended spring 36 and when this has been achieved the spring 36 with the tube 34 contained therein is removed from the mandrel 10 whilst the spring 36 is retained in its extended form by the material of the tube 34. The assembly is located in an oven at a temperature between 330° and 400°C for a predetermined period of time such that the PTFE will be softened. Softening of the material allows the stored energy in the extended spring 36 to cause the spring to compress and thus compress the convolutions of the tube 34 into close configuration. When this condition is reached the closely convoluted tube is heat set and stable with very close pitch convolutions. The spring 36 may then be removed from the tube 34.

Clearly the temperatures, material of the tube and sizes of the mandrel and tube given above are simply by way of example and should not be construed as restricting the invention in any way.

To produce a sheathed convoluted flexible tube as shown in Figure 10 a piece of tube 34 manufactured by any of the methods referred to above is cut to the desired length and, in the case of wire reinforced tube the wire 25 is wound back at each end 37 of the tube, for example for a distance of approximately .75 inches and is then trimmed off.

A short length of plain PTFE tube 38 of 0.056 inches internal diameter and 0.012 inches wall thickness is threaded onto the unwound tube 34 and the trimmed end of the wire 25 to cover one complete turn of the wire 25 and thus the cut end of the wire 25.

The tube 38 serves to protect the convoluted tube 34 against puncture by the extreme end of the wire.

An end fitting 39 with a spigot 40 adapted to be inserted into the convoluted tube is provided and the spigot 40 of this end fitting 39 is sleeved by a plain tube 41 of PTFE of

0.625 inches internal diameter and wall thickness of 0.020 inches. The sleeve 41 is conveniently 0.625 inches in length and when in position on the spigot 40 serves to provide a cushion for the end of the flexible convoluted tube 34 to seat upon and seal against without becoming damaged due to forces applied to the end fitting 39 when a subsequent swaging operation is carried out. The so sleeved spigot 40 is inserted into the end of the tube 34 the convolutions of which become flattened due to the insertion of the spigot 40.

A length of stainless steel tubular braid 42 is sleeved over the convoluted tube 34 from its free end (that is the end not yet provided with an end fitting) and when the braid is positioned over the tube 34 and the spigot 40 two ferrules 43 are located on the sheath. The free end of the tube is now provided with an end fitting 39 of the kind described above. The ferrules 43 (one only of which is shown) are now positioned at the ends of the tube 34 and over the spigots 40 of the end fittings 39. The fittings 39 are then permanently secured into the tube 34 by a swaging operation of the ferrules 43 which, as shown at the lower portion of Figure 10 tightly hold the braided tube 34 on the spigot 40 and also become pressed into a groove 44 of the spigot end 40 of the end fitting. If desired the ferrules 43 may be of such a length as to extend (as shown by the broken line 43a) over several convolutions of the sheathed tube 34. In this case the free end of the ferrule is expanded to allow the sheathed tube 34 to flex without chafing against the free ends thereof.

The invention is not restricted to the details given above since clearly tubes of a different diameter and wall thickness can be produced to meet any particular requirements. Clearly some uses of the tube do not require the provision of a metallic braid 42 nor, in all cases, is it necessary to retain the wire 25 as a reinforcement of the convoluted tube 34.

The references made above to the temperature required for stabilising the material are of course capable of modification depending upon the degree of heat set stability required. For example a tube which has been heat set at a temperature of 280°C will remain stable in use up to approximately 200°C. For stability at higher temperatures higher heat setting temperatures are required.

Clearly the invention can be put into effect using material other than PTFE for example plastics materials such as nylon, p.v.c. or polyester material may be used with of course suitable modification of stabilising temperatures in the case in which heat setting and stabilising is required. Whilst reference has been made to the use of wire 25 it is possible to use other materials such as pre-formed flexible metallic or plastics strip material to retain the convolution and, if retained, to provide a tube reinforement.

Two forms of pre-formed flexible strip are illustrated by way of example in Figures 11 and 12.

As can be seen the strip of Figure 11 consists of a U-shaped body portion 44 having outwardly directed flanges 45 at the free ends of the arms of the body. When in position the body 44 of the strip lies within the troughs of the convolutions of the tube 34 and the flanges 45 overlie part of the peaks of the convolutions. Such a pre-formed strip can conveniently be produced by extrusion.

The strip shown in Figure 12 has the same external contour as that of Figure 11 but differs in that the body portion is solid. This form of strip may also be produced by extrusion.

Strips of the form just referred to are designed to give greater support to the convoluted tube than can be achieved using a wire and thus the tube can withstand great stress and the peaks of the convolutions are protected against chafing or abrasion when the tube is under pressure and is subjected to flexing.

In a still further alternative a loose braid or mesh, for example of wire, may be applied to the tube before it is convoluted and this will also serve, in the convoluted tube, in which the braid or mesh sheath will also be convoluted, to provide resistance to chafing or abrasion of the convolutions of the tube when it is in service.

It is also possible to convolute and reinforce (if required) tubes made by winding unsintered p.t.f.e. tape onto a plain mandrel to produce a plain tube which is consolidated by subjecting it to a sintering process. After removal from the mandrel the tube so formed may be convoluted as described above.

Reinforced tubes of the kinds referred to above are, it is thought, capable of withstanding pressures higher than those normally catered for in convoluted tubes produced by methods such as below moulding or heat and pressure moulding.

WHAT I CLAIM IS:—

1. A method of producing helically convoluted flexible plastics tube comprising the steps of threading a pre-formed plain flexible tube over an axially movable non-rotatable plain surfaced cylindrical mandrel, moving said mandrel and tube through a rotary convolution forming head and applying, by means of the head, a convolution retaining element to the tube, the said head being so shaped as to wind the retaining element in helicial manner around said tube at preset pitch to convolute said tube, and thereafter either removing the convolution retaining element or allowing it to remain when the tube has set into convoluted form either by cold compression or heat treatment and removing the convoluted tube so formed from the mandrel.

2. A method of producing helically convoluted plastics tube as claimed in Claim 1 in which the convolutions are of close pitch including the steps of axially compressing the wound tube initially convoluting the tube and then

while on the mandrel to a closer pitch, than that the initial convolution the so compressed tube being retained, by retaining members, in such conditions during heat treatment and subsequent cooling, the retaining members are removed and a heat stable close pitch convoluted tube is removed from the mandrel, the convolution retaining element of the tube then being retained or removed.

3. A method of producing helically convoluted plastics tube as claimed in Claim 1 in which the convolutions are of close pitch including the step of locating a close pitch or touch pitch spring on the mandrel in tandem with the tube, extending the spring to a pitch approximately equal to the pitch of the tube convolutions and retaining same in such extended condition to a pitch approximately equal to the pitch of the tube convolutions and so retained, partially removing the convolution retaining element from the tube and rotationally threading the tube into or onto the extended spring, unwinding the remainder of the convolution retaining element to rotate the tube and 'screw' it into or onto the spring, subsequently removing the re-wound tube and subjecting it to heat treatment to soften the material thereof and allow the spring to return to its close pitch form to produce close pitch convolutions in the tubes, cooling the tube and either retaining or removing the spring.

4. A method of producing helically convoluted plastics tube as claimed in claims 1 or 2 in which the convolution retaining element is retained on the convoluted tube.

5. A method of producing helically convoluted plastics tube as claimed in any one of the preceding claims in which the convolution retaining element is pre-formed to have an external contour complementary to the convolutions to be formed in the tube, said convolution retaining element being wound onto a plain tube to compress it and form the convolutions therein.

6. A method of producing helically convoluted plastics tube as claimed in any one of the preceding claims including the step of securing an end fitting to each end of a convoluted tube.

7. A method of producing helically convoluted plastics tube as claimed in Claim 6 including the step of applying a reinforcing braid to the convoluted tube and securing it together with the tube to end fittings for the tube.

8. A method of producing helically convoluted plastics tube as claimed in any one of the preceding claims including the step of applying a braid or mesh loosely over a plain tube and subsequently convoluting the tube.

9. Apparatus for producing a helically convoluted flexible tube by the method claimed in any one of the preceding claims including a mandrel and a convolution forming tool, said mandrel being non-rotatable but movable axially through said tool, said tool being rotatable around said mandrel and being provided with a helical guide formation adapted to receive a convolution retaining element whereby in use the combined rotation of the tool and helical feed of the convolution retaining element serves to cause axial movement of the mandrel through the tool as the convolution retaining element is helically formed around the tube contained on the mandrel.

10. Apparatus as claimed in Claim 9 in which the tool is mounted on a rotatable backplate through which the mandrel may pass, the backplate carrying means for rotatably receiving a convolution retaining element supply spool and means for applying a restraining force to the spool to control its freedom to rotate thereby to provide tensioning means for the convolution retaining element.

11. Apparatus as claimed in Claim 9 in which the backplate is secured to a rotatable hollow mandrel adapted to be driven through gearing from a prime mover, the tool being mounted on said backplate through which the non-rotatable mandrel, and the tube to be convoluted passes during the application of the convolution retaining element to the tube.

12. Apparatus as claimed in Claim 9 or 10 or 11 in which the convolution retaining element applying tool comprises a disc-like element having a central aperture and a convolution retaining element guide hole extending from the periphery of the tool to the aperture, the tool being formed into a helical shape in the region of the aperture and having a convolution retaining element guide groove around the aperture.

13. Apparatus as claimed in any one of Claims 9 to 12 in which the non-rotatable mandrel is provided, after passing though the convolution forming tool, with adjustable clamps whereby a convoluted tube can be axially compressed to produced close pitch convolutions in the tube.

14. Apparatus as claimed in any one of claims 9 to 12 in which the non-rotatable mandrel is provided with means for clamping one end of a close pitch spring to enable it to be extended to receive a convoluted tube and thereafter to be released to enable it, during heat treatment of the tube, to return to its close pitch form to produce close pitch convolutions in the tube.

15. The method of producing helically convoluted plastics tube substantially as hereinbefore described with reference to the foregoing examples and as illustrated in the various figures of the accompanying drawings.

16. Apparatus for producing helically convoluted plastics tube substantially as hereinbefore described with reference to an as illustrated in the various figures of the accompanying drawings.

17. The method of producing helically convoluted plastics tube including end fittings

substantially as hereinbefore described with reference to and as illustrated in Figure 10 of the accompanying drawings.

18. Helically convoluted plastics tube when produced substantially as hereinbefore described with reference to and as illustrated in the several figures of the accompanying drawings.

Agents for the Applicant

WILSON GUNN & ELLIS
41–51 Royal Exchange,
Cross Street,
Manchester M2 7DB

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3 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

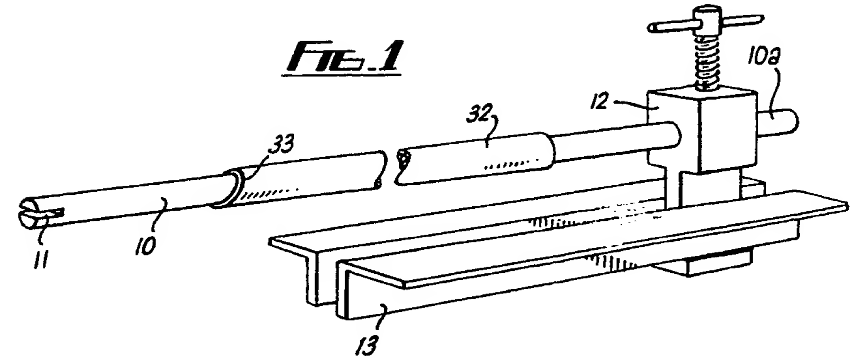


FIG. 1

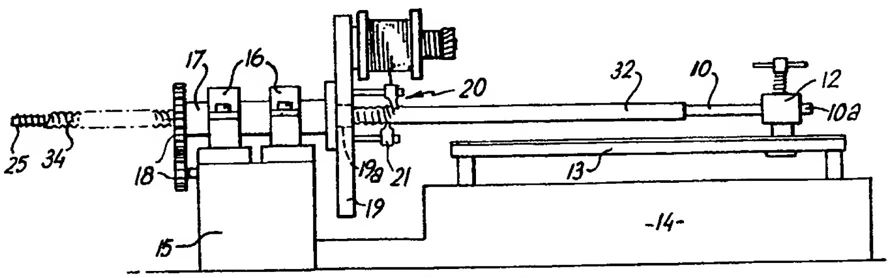


FIG. 2

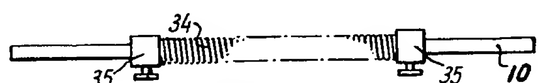


FIG. 3

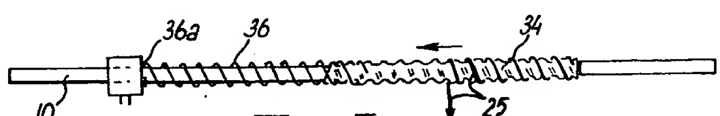


FIG. 4

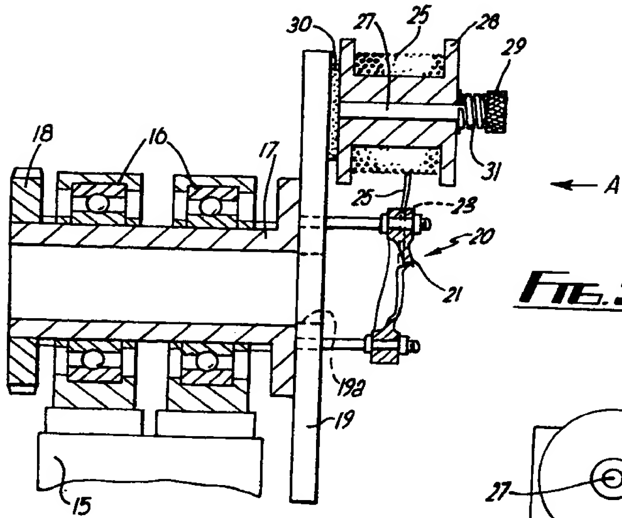


FIG.5

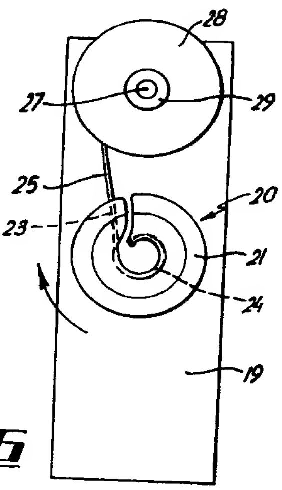
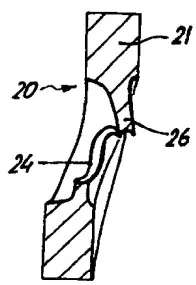


FIG.6

FIG.7



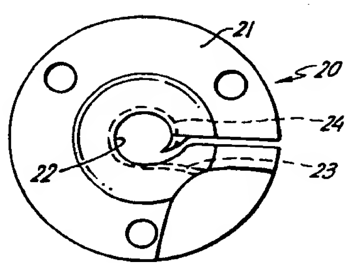


FIG.8

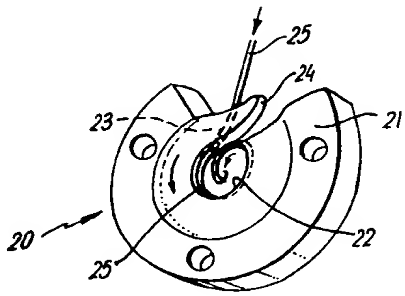


FIG. 9

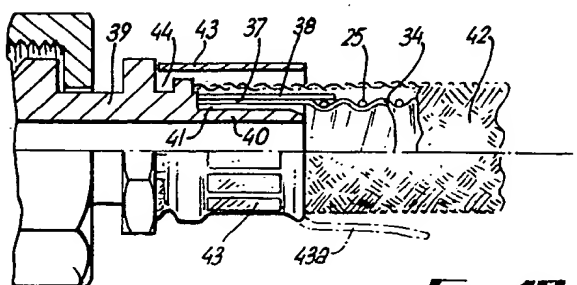


FIG. 10

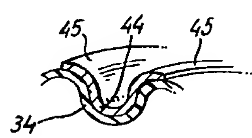


FIG. 11

FIG. 12